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SOFTWARE APPLICATIONS FOR BEAM TRACEABILITY AND MACHINE DOCUMENTATION AT ISOLDE

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Abstract

The ISOLDE facility at CERN requires a wide variety of software applications to ensure maximum productivity. It will be further enforced by two new applications; Automatic Save After set uP (ASAP) and Fast Beam Investigation (FBI). ASAP saves crucial time for the engineers in charge (EIC) during the physics campaign. It automatizes and standardizes a repetitive process. For each new set up, the EIC is required to document the settings of all important elements, before delivering beam to the users. FBI will be serving two different needs. First, it will be used as a beam traceability tool. The settings of every element of ISOLDE that could obstruct, stop or affect the beam will be tracked by the application. This will allow to understand better the presence of radioactive contaminants after each experiment at critical points in the facility. The second functionality will allow real time monitoring of the machine status during a physics run. FBI will be the most efficient way to visualize the status of the machine and find the reason that prevents the beam from the experimental station. Finally, an application has been developed to automatize with flexibility a sequence of pre-defined assignments, such as performing a measurement and setting a value to a device.

INTRODUCTION

ISOLDE is one of the leading research facilities in the field of nuclear physics. The latest addition, HIE-ISOLDE [1] increased the demand for beam time to conduct experiments. In such a demanding environment time is crucial. Even a few minutes gained from a repetitive task can account for hours gained within a year. These hours could be allocated in any other more productive manner. The three applications presented in this paper were conceived mainly with this achievement in mind. How to gain time and be more efficient. ASAP reduces the time the EIC is required to perform the task mentioned above, that takes place a minimum of once a week. FBI will contribute in efficiently resolving issues that hinder the users from receiving beam. In conclusion, the principle and the assignment possibilities of the Automation application are described.

AUTOMATIC SAVE AFTER SET-UP (ASAP)

The EIC is responsible to perform the beam set-up to a pre-defined destination. The specifications from the physics proposal needs to be fulfilled, meaning that the beam properties and transmission should be adequate to deliver the expected amount of beam to the users. Depending on the final destination this setting up procedure can require from a few hours to a few days. The longest duration concerns a beam reaching an experiment after HIE-ISOLDE which is the latest addition to the ISOLDE facility. In its current phase, ASAP does not include that area so details will not be mentioned here.

Tools used by the EIC While Setting up the Accelerators

Once the EIC verifies that the target used to generate the Radioactive Ion Beams (RIBs), is in good condition to provide beam, the set up can begin. After the beam is extracted from the target, it is guided through the beam line using different kinds of elements (separator dipoles, electrostatic quadrapoles and benders, beam steerers). A mass separation takes place either using the general purpose separator General Purpose Separator (GPS) or the High Resolution Separator (HRS). The beam, after this point consists mainly of the desired mass. It continues downstream, going through more elements, until it reaches the experimental station. The EIC controls all these devices via the equipment array application [2]. A series of beam diagnostics equipment provides critical information about the characteristics of the beam. The intensity is measured by a Faraday Cup (FC), vertical and horizontal position by Wire Grid (WG) and Wire Scanner (WS). The EIC needs to verify optimal transmission with the help of the FC, WS and WG while using the equipment array application to steer the beam accordingly. Once the EIC concludes the beam set up, the state of the machine needs to be logged. The reasons behind this are: a) to ensure that one can restore the facility to this approved state in the case of an unexpected event (e.g. power cut). b) Having stored the current state of the machine allows more easily discovering possible drifts in parts of the machine which would lead in loss in transmission efficiency. Every event that takes place in the facility is being described and logged in an application called logbook [3].

Traditional Process of Saving a Set-Up

The process of saving the state of the machine comprises of the following steps. a) From the equipment array application the EIC needs to save the file which includes all devices and their current values that results in an acceptable beam set-up. A descriptive name should be given to facilitate the identification of the specific situation for which the set-up took place (e.g. 170824_1137_GPS_SEP_13C16O.csv). The name typically includes a time stamp (‘YYMMDD_HHMM’), the part of the machine which represents a group of devices that are included in the file and the isotope used for the set

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up. The name should be included in an entry inside the logbook. b) The EIC makes sure to include screenshots of every wire scanner and wire grid in the same entry. In case of any problems during the experiment, cross-referencing the current state with the one in the screenshots is an easy way of discovering possible issues. c) In the same logbook entry as above, the current intensity for each of the FC in the beamline should be included. Also the calculated transmission after the separator magnet, until the last FC, before the experimental station should be included. d) Everything starts from the fact that the extraction of the beam from the target is well optimised. The values of several power supplies and other devices that the target system consists of, are always included in the entry of the logbook (e.g. target/line heating, extraction electrode position etc.). e) The high tension applied on the target is crucial and is logged in the entry. f) The configuration of the separator magnet(s) is also included as a screenshot. For every step mentioned above, the EIC has to retrieve the dedicated application where these values are visible and copy them into the logbook by hand. Also to capture a screenshot of the application, into the logbook. With many steps and values coming from several different devices and applications, this is a task that requires focus and no interruptions to ensure completeness. Even with all values included there can be differences between such entries since no template is followed.

Using ASAP to Save a Set-up

This application boasts one of the most minimalistic graphical interfaces at ISOLDE (see Figure 1). The EIC needs to choose from which of the two separator paths the beam originated, GPS or HRS. It is also required to select the final destination. For now the destinations include three beamlines: GHM, GLM and CA0. Optionally, if the target utilises mass markers, the EIC can select to which power supply they are connected (e.g. In Fig. 1 the power supply of oven one is connected to a potassium mass marker). Adding or removing materials that are used as mass markers is possible by the positive and negative symbols.

The EIC can choose not to include a device that could be malfunctioning or even whole devices groups (e.g. all wire scanners) if they are of no interest for a certain case. This is achieved by pressing the "excluded devices" button which brings up the small pop up window in green colour.

Once the EIC has configured the specifications then the "prepare" button should be pressed. In the background the application, based on the specifications, retrieves a list of devices that are part of the beam path specified. ASAP then retrieves the current values for all devices and creates automatically a csv file which can be used by the equipment array application. The file name respects the naming convention presented above. This is achieved by retrieving and combining information from different devices.

ASAP inserts all FC and starting from the one closer to the target, it first documents the current intensity and then retracts it in order to repeat the same with the next one. Since inserting the FC can cause brief instabilities in the current measurement the logic introduces a delay time of 2 seconds to allow the measurement to stabilise. To ensure accurate and realistic results ASAP documents the average out of 5 measurements.

ASAP will then open a series of panels that are similar to the different applications mentioned above. Beam diagnostics: ASAP will open dedicated panels for each wire scanner and wire grid within the specified beam path. The EIC can commence a measurement and once a satisfactory graph appears, press the "capture screen" button which will automatically take a screen shot of the panel and insert it as attachment to the entry in the logbook. Upon successful insertion to the logbook, ASAP will stop the measurement, retract the device and close the panel. High tension: This panel shows all information relative to the high tension applied to the extraction electrode (e.g. voltage applied, drain current measured etc.). Separator magnet(s): This panel shows all information relative to the separator magnets (e.g. magnetic field requested, isotope selected etc.). The EIC can choose to close the panel from the top right "x" button like any normal window. By doing so, the panel will not be included in the screenshots of the logbook entry.

ASAP will gather all information from the different applications mentioned above and will automatically generate a logbook entry. It will also include the target number and type. The csv file names created will also be included together with the full path where they were stored. Each FC measurement will be noted and transmission for each FC compared to the one after the separator will be included. All panels that the EIC chose to take screenshots of will be included as attachments.

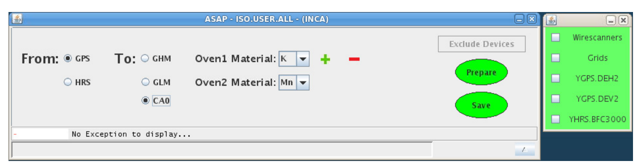

Figure 1: ASAP main panel with the excluded devices window open.

Future upgrades (phase two and three)

During phase 1, ASAP was to be tested by being used only in the low energy part of the facility. During this test period, ASAP would include in the logbook entry the value for all devices, even if some of them were not used. This was done to ensure that the correct values were stored in the corresponding devices.

With phase two of the application the entry will become smaller, including only the devices that are actually used. Moreover, the selection pop-up window of devices to be excluded will be upgraded. A more user friendly interface will replace the current one. The EIC will be able to select either whole group of devices or specific ones. FC devices will be included. ASAP could be used to set the reference values which will be used in the Fast Beam Investigation (FBI) application. Finally a csv file will also be generated and included as an attachment in the same entry. It will include all values mentioned in the entry.

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During phase three the remaining parts of the facility (REX-TRAP, REX-EBIS and the REX/HIE-ISOLDE linac) will be incorporated in ASAP.

AUTOMATION APPLICATION

Similar approach with the goal of automatizing a repetitive process has been made with this automation application. An Inspector-based [4] application using Python programming has been developed to automatize scripted controls and measurements. This application serves the purpose of automatizing sequences of actions with flexibility. An input text file describes the scripting of the tasks or assignments to achieve. Each line of the text file must represent a defined task followed by its arguments in between parenthesis. The list of possible tasks can be grouped in three categories: simple tasks of communication to a device for setting or getting a value, more complex tasks requiring several iterations or graphic representations and tasks related to the algorithmic of the scripting.

The first category of basic tasks (see Table 1) include several predefined communication modes with quadrupoles, Faraday cups and steerers (“FC”, “QP” and “STEERER” tasks). For those assignments the arguments to provide are at minima the name of the device and the value to set, but can extent to optional parameters, as the averaging number of the data to get. Two more general tasks of set and get a value are implemented for which the whole URL of the field, property and device need to be stated.

Table 1: Basic Tasks

Tasks	Description
FC	Inserts and measures or retracts a Faraday Cup
QP	Quadrupole set value or get data
STEERER	Steerer set value or acquire data
SET	Set value of specified device URL
GET	Get value of specified device URL

In the second category of tasks (see Table 2), more complex operations can be accomplished. A task called “SLITSCAN” performs a transverse profiling of the beam with a chosen slit and a selected Faraday cup or Silicon detector. The specification of the scan can be defined in the arguments of the task (continuous or step scan, range of the slit movement, averaging number for the acquisition, etc.). Another type of scan using REX or HIE-ISOLDE magnets is implemented in two different tasks for which the arguments stipulate the magnet regulation (current or field), the range of values to sweep and information related to the measurement.

Table 2: Complex Tasks

Tasks	Description
SLITSCAN	Beam profile using a moving slit and Faraday cup or Silicon detector
MAGNET	HIE magnets scan with Faraday cup or Silicon detector acquisition
MASSSCAN	REX separator magnet mass scan with Faraday cup acquisition
OPTICS	Measurement of all the optics elements values of HIE/REX-ISOLDE

The last category of tasks includes several algorithmic statements to rule the sequence of actions to be accomplished (see Table 3). The use of the tasks “CALL” and “LOOP” make the scripting of long sequence of actions more friendly to write in the input text file. For instance, multiple series of complex and basic tasks can be repeated, such as the quadrupole-scan method for transverse beam parameters measurement. The “CALL” tasks or the possibility to have several recursive inclusions enable systematic measurements of several hours to be directed within only few lines of scripting.

Table 3: Algorithmic Tasks

Tasks	Description
LOOP	Loop of selected tasks with or without increment
IF	If specified conditions are gathered the following tasks are to be included.
WAIT	Wait during a determined time
CALL	Call another text file to add up its sequence of tasks

Once the text file is loaded and the automation starts, the progress is evolving in a gauge bar and the list of tasks to accomplish is shown in a table (see Figure 2). The list of arguments is also displayed in the table, as well as the main results and the time elapsed after each task fulfilment. All the results are progressively saved in a main comma-separated-value document and each scan is saved in a separated document of the same type. Beam profile scans and magnet scans are displayed in scopes of the application that appears when clicking on dedicated sections: XT00, XT01, XT02 or XT03 lines for the beam profiles and “energy scan” for the magnet scans. To follow the evolution of the automation, the application pictures a large schematic of REX/HIE-ISOLDE linac and High Energy Beam Transfer lines (HEBTs) with several visual indicating the current state of the devices (Faraday cup, foils, slit, Silicon detector) inside the diagnostic boxes (inserted, extracted or moving).

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Figure 2: Automation application main panel.

The application additionally offers two different tools. When clicking on the “Stability” section, a table emerges with all the beam optics elements, their acquisition and set values, the average of their acquisition values and lastly the average and the standard deviation of the relative difference between the acquisition and set values. This part aims at detecting potential instabilities of the instrumentation for REX/HIE-ISOLDE linac and HEBT lines. Finally, from the last tool in the “PLOT FUNCTION” section, it is possible to subscribe to any chosen field of a device and draw its trend as a function of time. More sophistically, one is also able to select one field, as a function of another field chosen and acquire the evolution in a scope.

FAST BEAM INVESTIGATION (FBI)

All devices within the ISOLDE facility are accessible via the Java Api for Parameter Control (JAPC) [5] that acts as a standard CERN interface to the Front-End Software Architecture (FESA) [6] or the Function Generator/Controller (FGC) [7].

Every device is uniquely identified by a DeviceName and each of them exposes, via the API, a series of Properties that, in turn, contain a list of fields. The combination of the three elements is called a parameter and is uniquely identified by a string in the form: DeviceName/Property#field. As an example, the voltage of a quadrupole in the GPS separator will be acquired using YGPS.QP40-V/Acquisition#aqn. The number at the end of the name is incrementing the further away from the target the device is located.

The CERN control System runs on a dedicated Technical Network (TN) which is, for security reasons, separated from the General Purpose Network (GPN).

The FBI project is divided into two functionalities; Beam accounting and Beam traceability. Beam accounting will be responsible to keep track of every incident where beam has been deposited onto anything else but the experimental station. At the same time it will facilitate the operations group in providing statistics about beam delivery to the users. Beam traceability will provide information about the type of beam and its location in real time. To achieve these tasks the application needs to monitor in real time the status of a selected number of parameters, logging their values when necessary and notify the user in case of a problem. FBI is currently a work in progress.

The Beam traceability application is split in several components in charge of different functionalities.

A JAVA application running on a Linux machine on the TN will monitor a defined list of parameters and log their values in a table in an ORACLE database. The list of parameters to be monitored together with their reference and some extra information is also stored in a configuration table in the same database. The JAVA application is notified every time a parameter is added or removed from the configuration table and is able to start and stop subscriptions without the necessity to interrupt and restart the monitoring process. A diagram showing the respective parts and their communication can be seen in Figure 3.

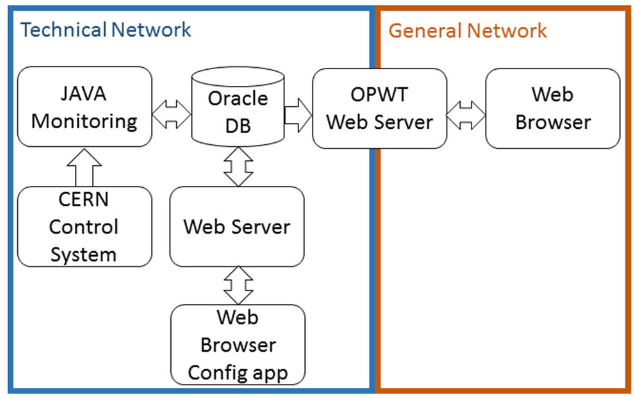

Figure 3: Each component of the FBI project and their connections.

Due to the relevant number of monitored parameters (close to ten thousand) and the rapid rate of event generation (every device ‘publishes’ a new value every 1,2s) some logic is implemented in the monitoring application to compare each received value with the last value stored in the database. If the two differ, the new value together with its timestamp, will be pushed into a buffer that will be written to the DB at regular intervals, avoiding overloading the database.

For security reasons and to avoid any possibility to interact directly with the control system from the GPN (where the visualisation layer runs) the configuration of the parameters to be monitored will be only possible from an application running on CERN’s TN.

This components run as a web application and allows importing/exporting configuration files for batch changes and simple modifications via a GUI.

To access the information stored in the DB and expose them in an easy consumable way a RESTful API running on a dedicated web server accessible from the GPN was developed. The server runs on CERN’s IT infrastructure and has access to the database on the TN. It also provides a series of additional services like authentication via Single Sign ON (SSO) and user authorisation based on the standard CERN login system. This way one can indirectly access some data from a browser maintaining a strict level of security and avoiding any possible data flow from the GPN to the TN.

The web applications are structured as a client -server model. The server on the back end is implemented in PHP,

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without any specific framework, using some custom classes to implement a RESTful API.

The front-end client is based on the Vue.js framework. The user interface has one view per section of the machine, each containing a simplified layout of the machine as an SVG file that can easily be acted on (change colour of element to match its status) with javascript.

The status of each element is computed on the server side, based on the reference value stored in the database and a series of logical conditions, configurable via the Config application. The set of reference values can be updated by the EIC at any time after setting up the machine with the click of a button. A draft version of the user interface is depicted in Figure 4.

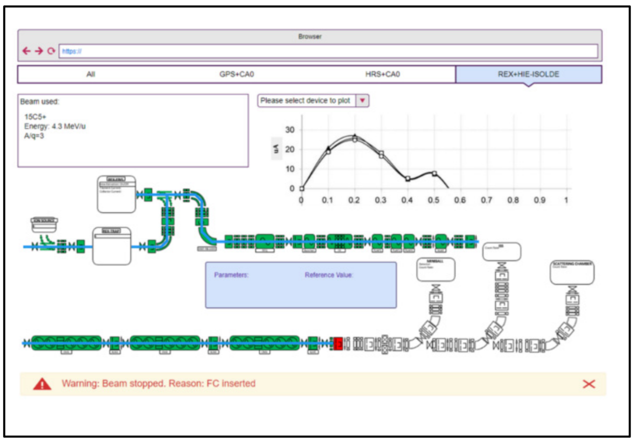

Figure 4: A draft design of the web application of FBI.

The Beam accounting part of the project complements the beam traceability mentioned above. It is also split in several components in charge of different functionalities.

Once all devices are identified they will be divided into groups. The goal is to create checkpoints where the beam could be deposited. Amongst the devices several of them are quite intrusive to the beam and therefore are considered as a checkpoint by themselves (e.g. Faraday cup, vacuum sector valve). Others, if they malfunction they could deviate the beam or change some of its characteristics (e.g. electrostatic element, super conducting cavity). For those devices checkpoints related to sectors of the beam line will be created.

The grouping of devices will be realised by using “virtual devices”. These virtual devices can be configured with additional logic which is not possible with an actual device. A virtual device can change its value depending on the value or state of other, actual, devices. For example virtual device “A” will become one if either the faraday cup “B” closes or the power supply “C” goes to a value that does not agree with the reference value. These virtual devices need to be created and declared to the Controls Configuration Database (CCDB). By including them in CCDB we will profit by the logging capabilities that are available.

A Graphical User Interface (GUI) will be created. Using this GUI, users will be able to access these virtual devices. It will be able to search either by device name or by some predefined location which will include a number of devices. The user will also be able to search for any devices where beam was deposited, by selecting a specific period of time. The GUI will provide information about the type and amount of beam that has been deposited on them. If no beam was deposited an informative message will appear. The GUI will be able to generate a report with the information mentioned above.

The application will automatically generate a weekly or monthly report with all cases where beam was deposited onto a device instead of being delivered to the experimental station.

Both parts of the FBI project will be used and verified on the HI-ISOLDE part of the facility. After a verification period the devices for ISOLDE and REX will be included.

CONCLUSION

ISOLDE in 2017 celebrates 50 years of experiments at CERN. A great part of this continuous operation is the fact that the facility is constantly upgrading its infrastructure. The last example is the addition of HIE-ISOLDE. Part of the infrastructure is the software used to operate the facility. With the applications described in this paper, operations will be reinforced with additional tools. ASAP and automation application, will standardise a repetitive procedure. FBI will make more evident any issue that might occur with the facility. This will potentially minimise the response time and even proactively diagnose and solve issues in parts of the machine that are not part of the current path to deliver beam to an experimental station.

REFERENCES

[1] HIE-ISOLDE, https://cds.cern.ch/record/1001782/files/CERN-2006-013.pdf

[2] E. Fadakis *et al.*,”Software Applications Used at the REX/HIE-ISOLDE LINAC”, in *Proc.* ICALEPC’17, Barcelona, Spain.

[3] eLogbook, https://ab-dep-op-elogbook.web.cern.ch/ab-dep-op-elogbook/

[4] V. Costa *et al.*, “Inspector, a Zero Code IDE for Control Systems User Interface Development.”, in *Proc.* ICALEPCS’17, Barcelona, Spain.

[5] *JAPC,* https://espace.cern.ch/be-dep-old/CO/APs_Section/SitePages/JAPC.aspx

[6] A. Guerrero *et al.*, “CERN Front-End Software Architecture for Accelerator Controls”, in *Proc. ICALEPCS’03,* Gyeongju, Korea.

[7] D. Calcoen *et al.*, “Evolution of the CERN Power Converter Function Generator/Controller for Operation in Fast Cycling Accelerators”, in *Proc. ICALEPCS’11, Grenoble, France, pp. WEPMN026.*